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CINE-ANGIOCARDIOGRAPHY OF THE MITRAL VALVE

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The severity of mitral regurgitation when associated with stenosis is often doubtful after clinical electrocardiographic and standard radiological examinations are completed. By the use of the available indirect methods for the assessment of mitral regurgitation, it is often impossible to distinguish between mild and moderate regurgitation, a vital distinction when considering a closed mitral valvotomy.

In the analysis of left atrial pressure tracings, attention has been directed to the height and shape of the V wave (Lagerlöf and Werkö, 1949; Gorlin *et al.*, 1952; Biörck *et al.*, 1953; Logan and Turner, 1953; Connolly *et al.*, 1955) and to the Y descent expressed as the RY/V ratio (Owen and Wood, 1955). While the use of the Y descent provides a guide to the type of valve lesion present, an occasional case of dominant mitral regurgitation has a small systolic wave and an RY/V ratio within the stenotic range (1.7). Dye dilution techniques have been employed to assess mitral regurgitation but detection of a slight degree is difficult (Korner and Shillingford, 1955). The technique of assessing the severity of mitral regurgitation by the injection of indicator into the left ventricle, while blood is sampled simultaneously from the left atrium and from a peripheral artery, suffers from the same inaccuracies due to inadequate mixing, and the distinction of mild and moderate regurgitation is impossible (Polissar and Rapaport, 1961; Jose and Bernstein, 1962). More recently the apex cardiogram has been used, but this method is insufficiently sensitive to distinguish between mild and moderate regurgitation (Nixon and Wooler, 1963). Angiocardiography with left ventricular contrast injection offers a means of directly visualizing regurgitation into the left atrium. Biplane radiography in the antero-posterior and lateral positions using a rapid serial film changer is the method generally employed (Björk, Lodin, and Malers, 1960; Steiner *et al.*, 1963); oblique projections and cine-radiography have also been used (Ross and Criley, 1962).

We consider that the method which most accurately assesses the various grades of regurgitation is cine-radiography following left ventricular contrast injection with the patient in the right anterior oblique position. In addition objective information is obtained concerning cusp mobility. In this paper, our experience with this technique as a pre-operative assessment for mitral valve surgery is described. We felt that the investigation would be valuable in mitral stenosis when there was clinical doubt as to the degree of regurgitation; in combined mitral and aortic valve disease when the dominant lesion was uncertain (in these a further cine-angiogram of the aortic valve was obtained following injection of contrast into the ascending aorta to assess the degree of aortic regurgitation); and in pure mitral regurgitation when there was a possibility of ruptured chordæ tendineæ.

Subjects and Methods

Thirty-two cine-angiocardiograms were obtained in 31 patients. They represent a small proportion of all cases of mitral valve disease seen during the past six years. There were 17 women and 14 men, whose

TABLE I

CORRELATION OF CINE-RADIOGRAPHIC AND CLINICAL FINDINGS IN 31 PATIENTS WITH MITRAL VALVE DISEASE

Case No.	Sex and age (yr.)	Dyspnœa	Palpation		Auscultation						Electrocardiogram			Cine-radiography		
			RV	LV	MSM	MDM	Length MDM	OS	3rd HS	Aortic area	Rhythm	RV	LV	Regurgitation	Cusp movement	
															Anterior	Posterior
1	F 26	2/4	++	+	3/6	4/4	4/4	+	0	0	SR	+	0	0	2/3	2/3
2	F 48	2/4	0	+	2/6	2/4	3/4	0	0	EDM	AF	0	0	0	0	1/3
3	M 27	2/4	0	+	4/6	3/4	3/4	0	1/4	ESM EDM	SR	RAD	+	1/3	0	0
4	M 56	2/4	+	0	3/6	2/4	3/4	0	2/4	EDM	AF	0	+	1/3	0	2/3
5	F 53	2/4	+	0	4/6	2/4	2/4	+	0	0	AF	+	0	1/3	1/3	0
6	M 50	3/4	++	0	3/6	2/4	4/4	0	0	0	AF	+++	+	1/3	0	0
7	F 55	2/4	+	0	2/6	2/4	3/4	+	0	0	AF	0	0	1/3	2/3	1/3
8	F 54	2/4	++	+	3/6	2/4	3/4	+	0	EDM	AF	+	0	1/3	1/3	1/3
9	F 53	3/4	+	0	3/6	2/4	4/4	+	0	0	AF	+	0	1/3	1/3	0
10	F 42	3/4	++	+	4/6	2/4	4/4	+	0	0	AF	RAD	0	2/3	2/3	0
11	F 47	3/4	0	++	4/6	2/4	2/4	+	0	0	AF	0	+	2/3	1/3	2/3
12	M 48	3/4	0	+	3/6	0	0	0	0	EDM	AF	0	+	2/3	0/3	0/3
13	M 46	2/4	++	+	3/6	2/4	3/4	+	0	EDM	SR	+	+	2/3	2/3	2/3
14	M 47	2/4	0	++	4/6	3/4	1/4	0	0	ESM	AF	0	+	2/3	0	0
15	F 57	3/4	+	0	2/6	1/4	3/4	+	0	0	AF	+	+	2/3	0	2/3
16	M 59	4/4	0	+	3/6	0	0	0	3/4	0	AF	0	+	2/3	1/3	1/3
17	F 53	3/4	0	+	3/6	2/4	2/4	+	0	0	AF	0	+	2/3	1/3	2/3
18	F 37	3/4	0	++	4/6	3/4	2/4	0	2/4	EDM	AF	0	+	2/3	1/3	0
19	M 47	2/4	+	+	4/6	3/4	3/4	0	0	EDM	AF	0	0	2/3	1/3	1/3
20	F 35	2/4	+	++	4/6	2/4	2/4	+	0	EDM	AF	RAD	+	2/3	2/3	1/3
21	M 49	3/4	+	+	3/6	3/4	3/4	0	0	ESM	AF	+	+	2/3	1/3	0
22	F 46	2/4	0	+	2/6	2/4	3/4	+	0	0	AF	0	+	2/3	1/3	2/3
23	F 46	3/4	++	+	4/6	2/4	2/4	0	2/4	EDM	AF	+	0	3/3	1/3	1/3
24	M 25	1/4	0	++	3/6	0	0	0	0	EDM	SR	0	4	3/3	2/3	2/3
25	F 25	2/4	++	0	4/6	2/4	2/4	0	3/4	0	AF	+	0	3/3	1/3	1/3
26	F 54	2/4	+	+	4/6	1/4	1/4	0	0	0	SR	0	+	3/3	?	2/3
27	M 53	3/4	0	++	4/6	0	0	0	2/4	0	AF	0	+	3/3	3/3	3/3
28	M 56	3/4	0	+	4/6	0	0	0	2/4	0	SR	0	+	3/3	?	?
29	M 60	3/4	0	+	4/6	0	0	0	0	0	SR	0	+	3/3	?	?
30	M 48	2/4	0	++	4/6	0	0	0	2/4	0	SR	0	+	3/3	1/3	1/3
31	F 31	2/4	+	++	4/6	2/4	2/4	+	2/4	EDM	AF	0	+	3/3	3/3	?
	32	3/4	+	++	4/6	1/4	1/4	0	2/4	EDM	AF	0	+	3/3	3/3	?

RV, right ventricle; LV, left ventricle; MSM, mitral systolic murmur; MDM, mitral diastolic murmur; OS, opening snap of mitral valve; 3rd HS, third heart sound in mitral area; EDM, early diastolic murmur; ESM, ejection systolic murmur; SR, sinus rhythm; AF, atrial fibrillation; RAD, right axis deviation.

ages ranged between 25 and 60 years. Each patient was examined clinically and by electrocardiography; the relevant findings are summarized in Table I.

In each case a National Institute of Health catheter with side-holes and a closed radio-opaque tip was introduced via a right brachial arteriotomy and passed retrogradely into the left ventricle. The patient was placed in the right anterior oblique position at 45°. The tip of the catheter was positioned as near the apex as possible, though in some cases this was not achieved owing to instability of the electrocardiogram. A test dose of 5 ml. of contrast medium was injected by hand, under screen control, to ensure that the tip lay free in the left ventricular cavity. 40–50 ml. of medium was then injected mechanically at a pressure of 100 lb. per sq. in. and the cine film exposed at 50 frames per second. In most cases, the medium was Urografin 76. Triosil '75', when it became available, was used for a short time, as its lower viscosity, and hence shorter injection time, was considered an advantage; but the high incidence of arrhythmia with this medium prompted a return to Urografin.

In the right anterior oblique projection, the mitral valve ring is roughly in profile, separating the left atrium from the left ventricle. The upper two-thirds of the valve plane corresponds approximately to the anterior (or aortic) cusp, and the lower one-third to the posterior (or mural) cusp; there is, however, some

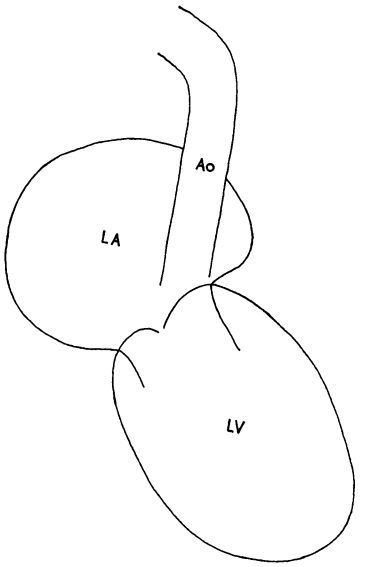


FIG. 1.—Diagram to show disposition of left heart chambers and mitral valve cusps in right anterior oblique position. (See text.)

overlap as the commissures lie oblique to the central ray, the antero-medial being caudal to the postero-lateral. The normal valve in systole shows slight doming into the left atrium. In diastole the cusps float open into the left ventricle (Fig. 1).

Each of the cine films was studied by two of us (R.S.O.R. and K.E.J.), initially independently and then together; the following features were noted and graded.

(1) *The degree of regurgitation.* We decided, after many and varied attempts, that objective measurements were unhelpful. Depending entirely on subjective impressions, we graded the regurgitation in the following way. *Grade* 0: No medium seen in left atrium. *Grade* 1: Small regurgitant jet (Fig. 2A). *Grade* 2: Large regurgitant jet (Fig. 3A). *Grade* 3: No discernible jet but obviously gross regurgitation (Fig. 4A).

The most difficult distinction was between Grades 1 and 2, but having established our criteria, we found there was almost no difference between our independent observations.

(2) *Cusp movement.* The degree of movement of each of the cusps was graded into 4: *Grade* 0: No movement. *Grade* 1: Minimal movement (Fig. 2). *Grade* 2: Moderate movement (Fig. 3). *Grade* 3: Excessive movement (Fig. 4).

It is important to estimate the movement relative to the valve ring and not to the heart as a whole, since there is considerable excursion of the ring during the cardiac cycle. In the presence of Grade 1 or Grade 2

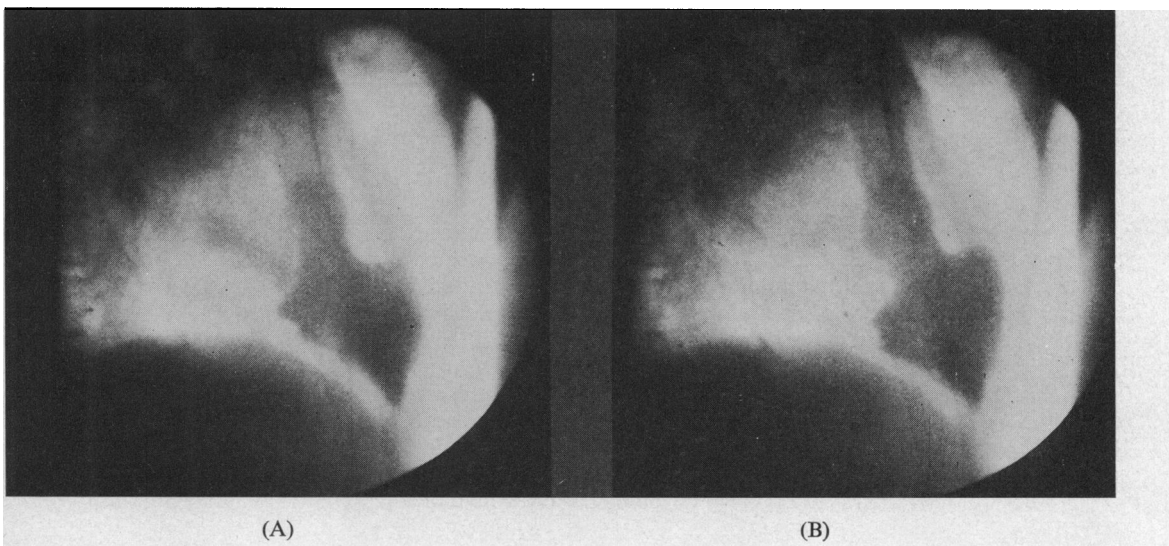
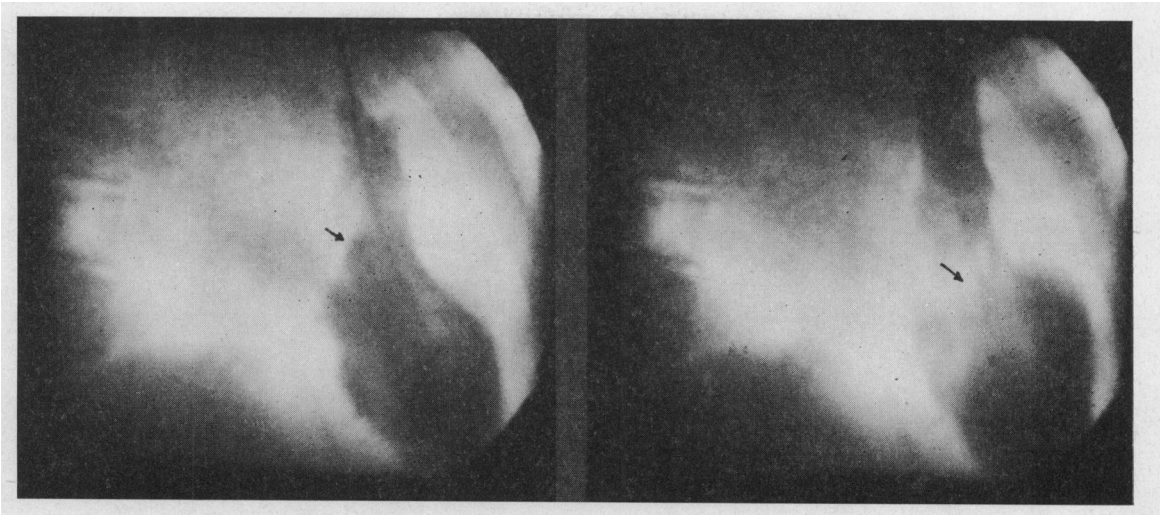
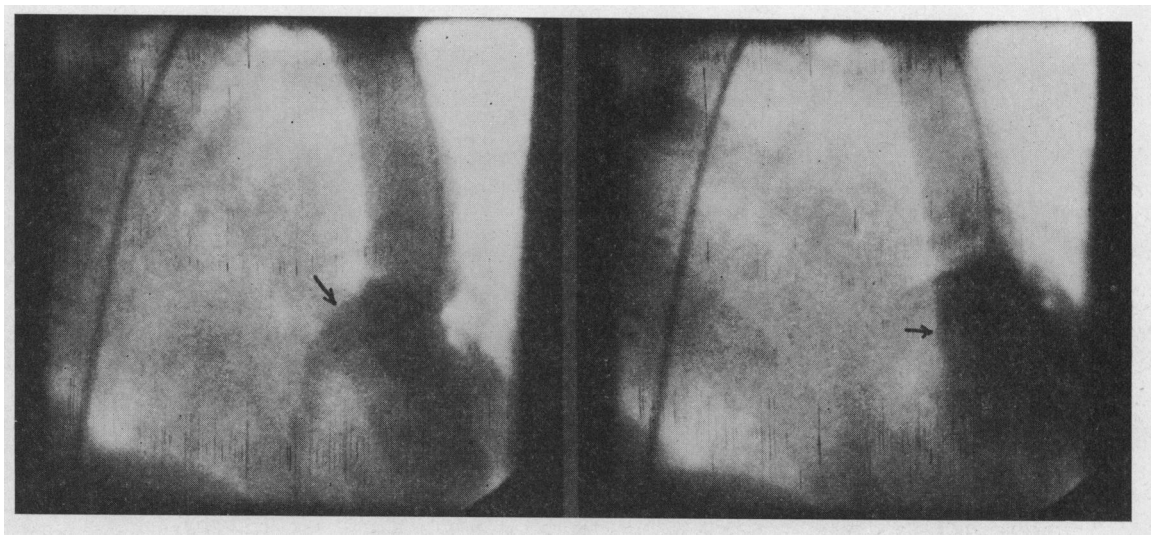


FIG. 2.—Case 4. Prints from individual frames of cine film. (A) Systole: example of small regurgitant jet, Grade 1. (B) Diastole: moderate movement of posterior cusp was observed on cine film.



(A) (B)

FIG. 3.—Case 18. (A) Systole: example of large regurgitant jet, Grade 2. (B) Diastole: moderate movement of anterior cusp (→).



(A) (B)

FIG. 4.—Case 31 (first examination). (A) Systole: diffuse filling of dilated left atrium with contrast, but no regurgitant jet visible, Grade 3. (B) Diastole: excessive movement of anterior cusps (→) due to ruptured chorda.

regurgitation, the cusp movement was relatively easy to assess; but with Grade 3 regurgitation it was more difficult, probably reflecting the loss of cusp substance in a grossly incompetent valve. However, in two patients with rupture of the chordae tendineæ, the excessive cusp excursion was easily seen, despite the presence of severe regurgitation.

RESULTS

The radiological findings are summarized in Table I. In 2 patients, no regurgitation was demonstrated, 7 had Grade 1 regurgitation, 13 had Grade 2, and 9 had Grade 3.

TABLE II

CORRELATION OF CINE-RADIOGRAPHIC AND SURGICAL FINDINGS AT OPERATION IN 14 CASES OF MITRAL VALVE DISEASE

Case No.	Cine-radiography			Operative and post-mortem findings				Post-operative progress
	Regurgitation	Cusp movement		Regurgitation	Stenosis	Comments on valve	Procedure	
		Anterior	Posterior					
1	0/3	2/3	2/3	N	S	Fibrosed, thickened	Valvotomy	*In statu quo* 3 mth.
2	0/3	0/3	1/3	N	S	Antero-medial commissure fused; orifice posterior	Valvotomy	Improved 6 mth.
3	1/3	0/3	0/3	N	M	Cusps mobile and fibrous	Valvotomy	Improved 3 mth.
4	1/3	0/3	2/3	Sl	S	Anterior cusp fibrous, thickened, and immobile	Valvotomy	Improved 6 mth.
5	1/3	1/3	0/3	N	S	Both cusps thickened, irregular, and immobile	Valvotomy	Improved 6 mth.
6	1/3	0/3	0/3	Sl	S	Cusps irregular	Valvotomy	*In statu quo* 6 mth.
9	1/3	1/3	0/3	N	S	Cusps very thickened and fibrous	Valvotomy	Improved 2 mth.
10	2/3	2/3	0/3	M	S	Antero-medial commissure thickened and calcified	Valvotomy	*In statu quo* 6 mth.
13	2/3	2/3	2/3	M	Sl	Anterior cusp normal; posterior cusp fibrosed and distorted	Valvotomy	Improved 1 yr.
14	2/3	0/3	0/3	M	N	Rolled edge anterior cusp; shortened chordæ posterior cusp	Repair not attempted	Chronic heart failure 2 yr.
18	2/3	1/3	0/3	S	N	No comment	Valvotomy attempted	Chronic heart failure 2 mth.
20	2/3	2/3	1/3	M	Sl	Anterior cusp normal; posterior cusp fibrosed and distorted	Valvotomy	Died 10 mth.; heart failure
21	2/3	1/3	0/3	M	Sl	No comment	Valvotomy	Died 6 mth.; heart failure
27	3/3	3/3	3/3	Died during induction of anæsthesia; necropsy showed ruptured chordæ of both cusps; parachute deformity of posterior cusp				
31	3/3	3/3	?	S	N	Ruptured chorda of anterior cusp	Repair of ruptured chorda	Deterioration at 4 mth.
	3/3	3/3	?	S	N	Rupture of two of anterior cusp chordæ	Attempted repair	Died after operation

N, none; Sl, slight; M, moderate; S, severe.

Operations were carried out on 14 patients, and a further patient died during induction of anæsthesia. The operative and post-mortem findings are summarized in Table II. Our assessment of regurgitation agreed well with the surgeon's findings at operation. The principal exception was that in some cases of Grade 1 regurgitation, none was observed by the surgeon. This probably indicates that contrast injection is a more sensitive method of detecting minor degrees of regurgitation. Unfortunately, the surgeon did not comment on cusp movement in every case, but in those cases where comments were made they agreed well with our observations with one exception (Case 3).

Five patients with Grade 2 regurgitation had a closed valvotomy (Cases 10, 13, 18, 20, and 21); 4 of these deteriorated or died within one year. On the other hand, of the 5 patients with Grade 1 regurgitation who had a closed valvotomy (Cases 3, 4, 5, 6, and 9), 4 are symptomatically improved, and the other is unchanged. Grade 2 regurgitation seems, therefore, to contraindicate closed mitral valvotomy.

Two patients with Grade 3 regurgitation had excessive cusp movement and were thought to have ruptured the chordæ tendineæ. One (Case 27) was in chronic left ventricular failure and died during induction of anæsthesia before a repair was attempted. At necropsy, there were ruptured chordæ of both cusps. In the other patient (Case 31) (Fig. 4), a successful repair of a ruptured chorda on the anterior cusp was performed, with disappearance of the apical pan-systolic murmur, and dramatic symptomatic improvement. However, four months later there was sudden deterioration, and a second cine-angiocardiogram again showed gross regurgitation with excessive movement of the anterior cusp, due to recurrence of chordal rupture. This patient subsequently died following a second attempt at chordal repair.

Discussion

Cine-angiocardiography following contrast injection into the left ventricle offers the best method of studying the regurgitating jet through the mitral valve: in addition it provides information on the structural abnormality that will be encountered at operation. Ross and Criley (1962) describe this technique in 16 patients using the right anterior oblique projection; they describe the characteristic cine-angiographic features of mitral regurgitation, and conclude that it provides a sensitive method of detecting slight degrees of regurgitation: but they make no attempt at quantitation.

The two main criteria suggested for assessing regurgitation are speed and density of left atrial opacification (Steiner *et al.*, 1963) and relative filling of left atrium and aorta (Björk *et al.*, 1960). Both depend on heart rate and rhythm, stroke volume, chamber size, and mixing of contrast with blood; the latter in particular is hampered by ectopic beats which may result in mitral regurgitation but fail to open the aortic valve. We consider that an assessment based on jet size rather than contrast density and volume is less dependent on these factors and therefore less likely to be misleading.

In all our patients the contrast injection was followed by a run of ectopic beats. Regurgitation through a normal mitral valve has been shown to occur during asystole, bradycardia, sinus arrhythmia, and compensatory pauses following ectopic beats: in each instance, a lengthened phase of diastasis seems to be the important factor (Stauffer and Oppenheimer, 1958; Paul *et al.*, 1958). This is quite the opposite situation to a series of rapid beats with shortened diastolic pauses. As there was good correlation of radiographic and surgical assessment of regurgitation in our 14 patients who came to operation, all of whom had ectopic beats, it is felt that this arrhythmia did not introduce significant inaccuracy.

No serious complications occurred in this series. Two patients were found to have an absent radial pulse following the arteriotomy, but in neither patient were there symptoms or other signs to suggest ischæmia in the hand. Ventricular standstill following contrast injection occurred in one patient, but normal rhythm was rapidly restored by external cardiac massage. Right brachial arteriotomy is preferred to percutaneous transfemoral catheterization for two reasons. First, we consider that pressure injection into the left ventricle using an open-ended catheter carries a greater risk than one with a closed end and side-holes; and secondly, it is easier to manipulate a catheter into the left ventricle from the brachial artery than from the femoral artery, particularly with associated aortic stenosis.

In conclusion we consider that the principal application of this technique is to help in deciding on the appropriate surgical treatment. In the presence of mitral stenosis, regurgitation of Grade 2 severity is an indication that open-heart surgery with valve repair or replacement is required; whereas those with Grade 1 regurgitation are considered to be suitable for closed transventricular

valvotomy. The second application is to help to determine the dominance of mitral and aortic valve lesions, in particular by comparing mitral and aortic regurgitation with left ventricular and aortic contrast injections. The third application is to provide some information on the anatomical abnormality in the valve. Movement of the individual cusps can usually be assessed, and a pre-operative diagnosis of rupture of the chordæ tendineæ may be possible.

Summary

Thirty-two cine-angiocardiograms were obtained in 31 patients following left ventricular contrast injection with the patient in the right anterior oblique position. The mitral valve has been studied with particular regard to assessing regurgitation and cusp movement. The results are correlated with clinical, operative, and post-mortem findings.

It is suggested that the technique is helpful in selected cases of mitral valve disease: to determine the appropriate surgical approach (those with Grade 2 regurgitation are unsuitable for closed valvotomy); to assess the relative severity of mitral and aortic regurgitation; to diagnose rupture of the chordæ tendineæ.

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